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Deep learning-based pesticides prescription system for leaf diseases of home garden crops in Sri Lanka

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***Abstract* - The study proposes a deep learning-based pesticides prescription system for leaf diseases of home garden crops in Sri Lanka. It is an intelligent system to get suitable pesticides prescriptions for plant leaf diseases. Home gardening has become popular and is rapid because of the current pandemic situation. However, plant diseases are a major problem in gardening activities, even in a home garden or in a commercial garden. Identifying and finding a solution for the plant disease is a big challenge for home gardeners rather than commercial farmers. The proposed system of deep learning-based pesticides prescription system for leaf diseases of home garden crops in Sri Lanka will be the best solution for identifying and finding a solution to the plant diseases. The system is using a trained model for prescribing pesticides. The model was built using the deep learning method and trained in the supervised learning process. The convolutional neural network algorithm was used in the model. Transfer learning with AlexNet pre-trained model was used to increase the performance in the proposed solution and the best accuracy of 88.64% was achieved in the experiments.**

Keywords - convolutional neural network, leaf diseases, Machine Learning, pesticides

I. INTRODUCTION

Agriculture is one of the major livelihoods in Sri Lanka. People are engaging in cultivation in commercial gardens and also at a smaller level, in home gardens. While engaging in gardening, diseases to the crops are one of the major problems. Commercial farmers may have some knowledge of crop diseases and pesticides, but home gardeners do not have much knowledge of them. Even in some cases commercial farmers also fail to identify some diseases. So, in that situation, both must consult with some agricultural experts to find a solution. Home gardeners, however, don't have the luxury of time to spend consulting experts to find solutions to these diseases. So, they may search and find some unsuitable pesticides through the Internet or somewhere else and spend their money on it. In most cases, this may not work and thus demotivated, may even leave their home gardening activity. A smart solution to solve this problem may be feasible.

Deep learning-based pesticides prescription system for leaf diseases of home garden crops in Sri Lanka is a smart solution for this problem. A person without proper knowledge of crop diseases and pesticides also can use this system. Using this system, a user can simply input an image of a leaf that was affected by the disease and get the appropriate pesticide to cure that disease, as the output. Some diseases can't be easily identified by even an experienced farmer, so it will be a challenging thing for home gardeners. But this system can easily identify the disease and prescribe the pesticide as well. The system mostly focuses on home garden crops, but whatever the crop in the home garden, it is also cultivated in commercial gardens. So, the system is not limited to a home garden, it can be used in a wide range like home gardens and larger gardens as well. Home gardeners would be most benefited by this proposed system.

The proposed system is using a trained model for prescribing pesticides. The model was build using the deep learning method and trained in the supervised learning process. The convolutional neural network algorithm was used in the model. The transfer learning method was used to increase the performance of the model. AlexNet was used as the pre-trained model for the transfer learning process. So, using this system the users can easily get the suitable and correct pesticide prescription for the leaf diseases.

II. LITERATURE REVIEW

In [1] authors evaluate the applicability of deep convolutional neural networks for the classification of plant diseases. They focused on two popular architectures, namely AlexNet and GoogLeNet. They analysed the performance of both these architectures on the PlantVillage dataset by training the model from scratch in one case, and then by adapting already trained models using transfer learning. In the case of transfer learning, they re-initialize the weights of layer fc8 in the case of AlexNet. They have achieved an accuracy level of 99.35%.

In [2] authors proposed a deep convolutional neural network model based on AlexNet and GoogLeNet to identify apple leaf diseases. The AlexNet gave a good recognition ability and obtains an average accuracy of 91.19%.

In [5] authors proposed a plant disease identification model framework based on deep learning. The RPN algorithm is used to train the leaf dataset in the complex environment, and the frame regression neural network and classification neural network is used to locate and retrieve the diseased leaves in the complex environment. The Chan–Vese algorithm is used to segment the image of diseased leaves. Resnet-101 was selected as the pretraining model, and the network is trained by using the dataset of disease leaves under a simple background. According to the comparison results, the average correct rate of their proposed method is 83.75%.

In [7] authors used the K-means clustering method for the segmentation of the image. They implemented their proposed methodology using Optimized Deep Neural network with Jaya algorithm in Python platform. The performance of their proposed method DNN-JOA is estimated and compared with the performance of existing classifiers such as ANN, DAE, and DNN. Using the

DNN_JOA classifier the highest accuracy is achieved for the blast affected leaf image which is 98.9%.

In [8] authors used K-means clustering, Support Vector Machine, and advance neural network for making an image classification model. K-Means algorithm is used to cluster the images, and then multiclass SVM is used for the classification process. The average accuracy of the classification of the proposed method is 95.83%.

III. Methodology

The system of Deep learning-based pesticides prescription system for leaf diseases of home garden crops in Sri Lanka has a trained model to prescribe pesticides for leaf diseases. So, in the proposed solution, the deep learning method was used, and the model was trained by a supervised learning approach. The convolutional neural network is a kind of deep neural network and it's commonly used to analysing visual imagery. It's a regularized version of multilayer perceptron. As the research is based on analysing the images, in the model training, Convolutional Neural Network has been used and the transfer learning technique also has been used to get the advantage of the AlexNet model. The high-level architecture diagram of the proposed system is shown in Fig. 1.

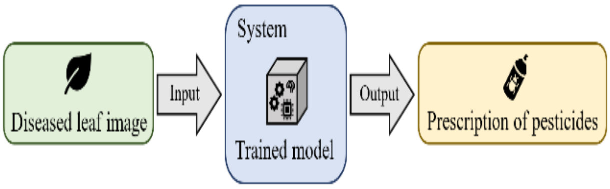

Fig. 1. The high-level architecture of the proposed system

Using transfer learning to train a model is more efficient than training a model from the scratch, and transfer learning has a higher start, higher slope, and higher asymptote. So, in the proposed system, the transfer learning technique has been used to increase the performance level and save time. The performance graph of the model with transfer learning and without transfer learning is shown in Fig. 2.

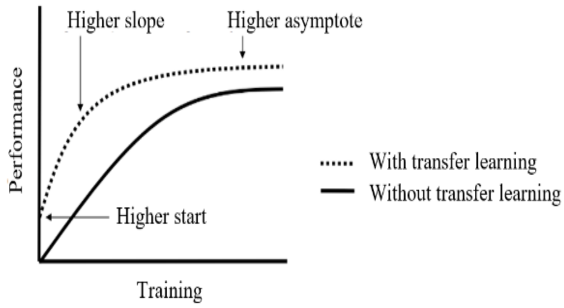

Fig. 2. Performance graph of learning types

The AlexNet model was used as the pre-trained model in the transfer learning process because the AlexNet is one of the best models which trained with a huge amount of data. The architecture of the AlexNet model is shown in Fig. 3. During the model training in the proposed system, the last layer of the AlexNet was reshaped and trained.

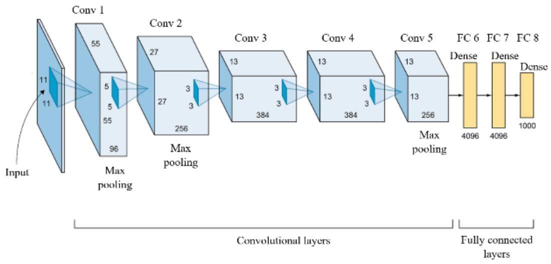

Fig. 3. The architecture of the AlexNet model

The dataset of images for training the model was collected from the Internet. As the research is focusing on Sri Lankan plants, it's difficult to find many plant types on the Internet. So, here only three types of plants and only twelve different diseases of those plants are used for the research. The images are in RGB colour format, and the size of the images is 256 x 256. Nineteen thousand and sixty-four leaf images were collected as the dataset. The dataset has twelve different diseases on three types of plants. Dataset also has healthy leaf images of those three plants. So, in the dataset, there are fifteen different types of classes available. Some sample images from the dataset are shown in Fig. 4.

Fig. 4. Sample images from the dataset

The data of pesticide details are also needed for model training to be used as the labels. Pesticides are called chemical control for plant diseases. Some diseases can't be cured by applying any chemicals. In this case, if the disease is severe, it must remove the affected plant from the garden. There will be a different chemical to control each leaf disease of crops. The chemical control methods of the selected twelve leaf diseases have been collected from the datasheets on the Internet. To control the leaf disease, the gardener must use a pesticide that contains the chemical which can control the specific disease. Then using the chemical control method details, the suitable pesticide details are also collected from the Internet. Since there are a lot of pesticide brands available, brands available in Sri Lanka should be identified. Thereafter, the prescribed pesticide can be locally bought by the customers. According to the findings in Table I, eleven diseases can be controlled by pesticides and one disease has no chemical control. The other three classes are healthy which do not need any usage of pesticides. So, now the dataset has nineteen thousand and sixty-four leaf images which fall under fifteen classes and has the pesticides data with the suitable chemical control methods of those diseases.

The experiment was done in the Jupyter Notebook editor using Python programming language. The model training was done using PyTorch open-source machine learning library. In addition to that, some python libraries also have been used.

Another important thing in the machine learning experiment is dataset preparation. The dataset has to be split for training, validation, and testing. So, the dataset was split as 80% for training, 10% for validation, and 10% for testing.

TABLE I. DISEASE AND PESTICIDE DETAILS

Plant	Leaf Disease	Chemical Control	Pesticide
Bell pepper	Bacterial spot	Copper fungicide	Manar Maneb
Bell pepper	Healthy	No chemical needed	No pesticides needed
Potato	Early blight	Mancozeb	Hayleys Mancozeb
Potato	Healthy	No chemical needed	No pesticides needed
Potato	Late blight	Mancozeb	Hayleys Mancozeb
Tomato	Bacterial spot	Copper fungicide	Manar Maneb
Tomato	Early blight	Mancozeb	Hayleys Mancozeb
Tomato	Healthy	No chemical needed	No pesticides needed
Tomato	Late blight	Mancozeb	Hayleys Mancozeb
Tomato	Leaf mold	Chlorothalonil	Ronil Chlorothalonil
Tomato	Mosaic virus	No chemical control	No pesticides available
Tomato	Septoria leaf spot	Chlorothalonil	Antracol Propineb
Tomato	Target spot	Chlorothalonil	Antracol Propineb
Tomato	Two-spotted spider mite	Abamectin	Mig Abamectin
Tomato	Yellow leaf curl virus	Imidacloprid	Kobra Imidacloprid

The training dataset will be used for training the model. The validation dataset will be used for frequent unbiased evaluation of the model. This will be used to fine-tune the model's hyperparameters. The test dataset will be used to do the unbiased evaluation of the final trained model after the completion of training.

The model was trained in the system which has the CPU configuration of Intel(R) Core (TM) i7=4510U CPU @ 2.0GHz and the memory configuration of 8.0 GB DDR3. The dataset has a huge number of files, with nearly a thousand images per class. It is a very time-consuming task with the normal CPU. To minimize the training time, it must use a GPU. In the model training, the GPU of NVIDIA GeForce 840M was used in the system.

In the dataset, the images may not be of the same size. Most neural networks expect a fixed image size. So, it must transform the image into a specified size before loading the data to train the model.

In the proposed system, the transfer learning method was used and the AlexNet model was used as the pre-trained model for that. Therefore, it must reshape the last layer of the AlexNet before training. In the proposed system, currently, there are fifteen classes. According to that, while initializing the model, it must reshape the number of neurons in the last layer to fifteen.

In neural network training, the optimizer is used to change the attributes like weight, biases, and learning rate to reduce the loss. It makes the training process fast.

The important thing in the experiment is the model training. Training the model means, learning the best values for the weights and bias from the examples. In supervised machine learning, the algorithm builds a model by examining many examples and try to find a model that minimizes loss. The model was trained with five hundred epochs. The learning algorithm will find the pattern in the training data that map the input data attributes to the target, and it outputs a model that captures these patterns.

IV. RESULTS AND DISCUSSION

The training process took six hundred and twenty-nine minutes and thirty-five seconds to finish the five hundred epochs. As a result of the experiment, the best accuracy of 88.64% was achieved during the training. The accuracy change over the number of the epoch is shown in Fig. 5, and the loss change over the number of the epoch is shown in Fig. 6.

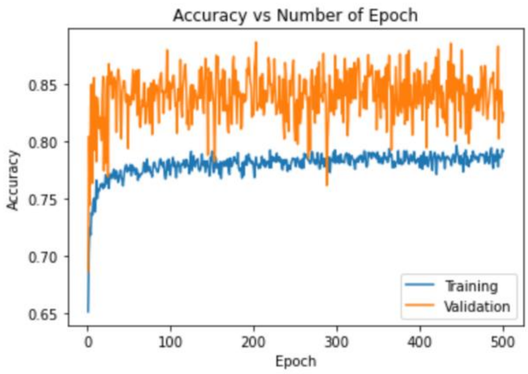

Fig. 5. Accuracy graph of training

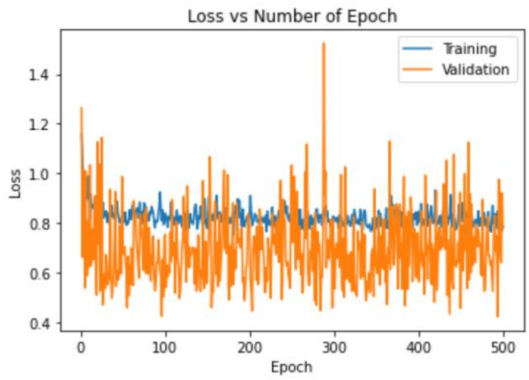

Fig. 6. Loss graph of training

The evaluation process is an important step in machine learning experiments. Through the evaluation process, one can find how well the trained model is performing. There are some evaluation metrics to measure the quality of the machine learning model. To evaluate the model, the test dataset can be used. This set of data is fully new and unseen data to the model. So, unbiased results of the evaluation can be gained from this. So, for the evaluation process, first, a confusion matrix is obtained as shown in Table II.

TABLE II. CONFUSION MATRIX FOR TEST RESULT

96	4	1	0	0	0	0	0	0	0	0	0	0	0	0
1	148	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	98	0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	15	1	0	0	0	0	0	0	0	0	0	0
0	0	9	7	64	3	0	0	8	1	0	3	1	4	0
0	0	0	0	0	207	0	0	0	0	0	2	4	0	1
3	0	0	0	1	10	48	1	9	4	0	7	10	3	4
0	1	0	0	0	0	0	158	0	0	0	0	0	0	0
0	0	0	0	4	3	2	4	159	5	0	3	5	2	5
0	0	0	0	0	1	0	1	1	85	0	2	1	1	4
0	0	0	0	0	0	0	0	0	0	37	0	0	1	0
0	3	1	0	0	1	0	1	1	1	3	164	3	0	0
0	1	0	0	0	1	0	17	0	0	0	1	110	11	0
2	0	0	0	0	0	0	8	0	0	0	0	17	136	6
1	0	0	0	0	0	0	0	0	1	0	0	0	0	163

Then to evaluate the model, the accuracy, precision, recall, and F1 score must be calculated.

Accuracy = Correct predictionsTotal number of predictions (1)

Precision =True positives(True positives + False positives) (2)

Recall =True positives(True positives + False negatives) (3)

F1 =2 * (Precision * Recall)(Precision + Recall) (4)

According to the results shown in Table III, for each evaluation matrices, the performance of the model can be evaluated.

TABLE III. EVALUATION OF RESULTS

	Precision	Recall	F1 score
Class 0	0.92	0.95	0.94
Class 1	0.94	0.99	0.97
Class 2	0.90	0.98	0.94
Class 3	0.68	0.94	0.79
Class 4	0.91	0.64	0.75
Class 5	0.92	0.97	0.94
Class 6	0.96	0.48	0.64
Class 7	0.83	0.99	0.91
Class 8	0.89	0.83	0.86
Class 9	0.88	0.89	0.88
Class 10	0.93	0.97	0.95
Class 11	0.90	0.92	0.91
Class 12	0.73	0.78	0.75
Class 13	0.86	0.80	0.83
Class 14	0.89	0.99	0.94
Macro avg	0.88	0.87	0.87
Accuracy	0.88		

The experiment was carried out by using different methods to find a better solution for the dataset. During the experiments, the CNN model was trained from scratch by using the selected sample from the dataset with a selected number of epochs. The accuracy and loss graph of the CNN model training is shown in Fig. 7 and Fig. 8. The model using transfer learning with AlexNet was trained by using the same selected dataset sample with the same selected number of epochs. The accuracy and loss graph of the transfer learning with AlexNet model training is shown in Fig. 9 and Fig. 10. Using the same selected sample dataset, the experiment was also carried out by using the SVM classifier. The accuracy result of each experiment is shown in Table IV.

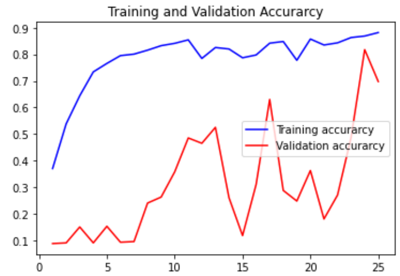

Fig. 7. Accuracy graph of CNN training

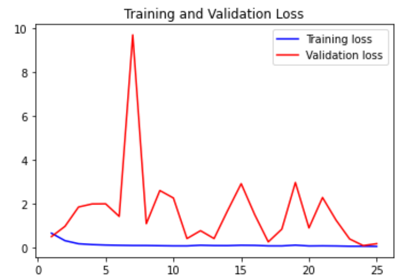

Fig. 8. Loss graph of CNN training

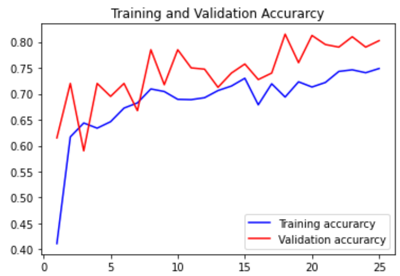

Fig. 9. Accuracy graph of AlexNet transfer learning

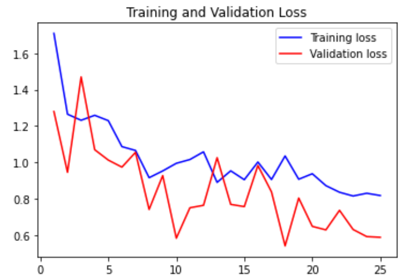

Fig. 10. Loss graph of AlexNet transfer learning

TABLE IV. ACCURACY OF EXPERIMENTAL RESULT

	Accuracy
CNN from scratch	69.75%
SVM	73.13%
Transfer learning with AlexNet	81.50%

According to the above results, transfer learning with AlexNet gave the best accuracy level. Therefore, this will be the best fitting method for the dataset. In the final implementation for the proposed system, the model training was carried out by using the method of, transfer learning with the AlexNet model. An example input of a diseased leaf image to the implemented system is shown in Fig. 11, and the pesticide prescription from the system for that input is shown in Fig. 12.

```
# Select a random image
selected_image = select_random_img()

Plant :  Tomato
Disease :  Septoria leaf spot
```

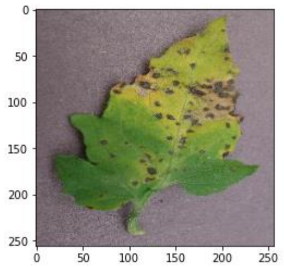

Fig. 11. The sample input image to the system

```
# Get prescription
get_prescription(selected_image)

Pesticide prescription for the leaf disease
*******************************************
Identified plant :  Tomato
Identified disease :  Septoria leaf spot
Prescribing chemical control :  Chlorothalonil
Prescribing pesticide name :  Antracol Propineb
```

Fig. 12. A prescription from the system for the input

V. CONCLUSION

As Sri Lanka is an agricultural country, a solution for leaf diseases is an important thing. According to the current pandemic situation, the need for a smart solution emerged. To solve this issue using a computerized system, multiple machine learning models were trained and tested. According to the experimental results, the proposed system is performing well in prescribing the most suitable pesticide for leaf diseases. There may be some existing systems to predict plant diseases, but the proposed system directly predicts suitable pesticides and it's a localized system for Sri Lanka. So, the proposed system, Deep learning-based pesticides prescription system for leaf diseases of home garden crops in Sri Lanka will be a great solution.

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